SOIL CONSERVATION

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STUDIES OF RESERVOIR SILTING

By Carl B. Brown[1]

Elk City, Okla., constructed a water-supply reservoir in 1925 at a cost of $325,093. After 6 years' use, excessive silting made it necessary to raise the spillway 2 feet to provide adequate storage. In August 1935 the lake was estimated to have lost 48 percent of its original capacity from silting. This reservoir is the second which Elk City has had, the first having silted up at the time the present lake was built. With a 48-percent capacity loss in the present lake, the city is already making plans for constructing a new dam, the water supply now available being insufficient for municipal needs. The watershed

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New stream channel nearly completed by general silting and deposit of a natural levee through the center of the original reservoir. Dunlop Reservoir, Chattahoochee River, Gainesville, Ga.

above the present reservoir is over 85 percent in cultivation.

Old Lake Austin on the Colorado River at Austin, Tex., was completed in 1893 with a capacity of 18 billion gallons at a cost of $1,400,000. In the 6.75 years until April 7, 1900, when the dam was washed out by flood, the reservoir had lost 48 percent of its capacity by silting. This figure converted into direct economic loss on the capital invested is equivalent to $93,000 per year. In 1913 a new dam was constructed at Austin which impounded a reservoir of 10.5 billion gallons. A survey made in 1926 showed that silt had displaced more than 95 percent of the original water storage capacity of the new lake in the space of 13 years.

Diminishing Capacity

Waco, Tex., completed in 1930 a storage reservoir which, together with appurtenant water-supply developments, cost about $7,000,000. A survey by the Soil Conservation Service in 1935 showed that the reservoir had filled 12.38 percent with silt, or at the rate of 2.48 percent a year. Unless steps are taken to reduce this exorbitant rate of filling, the storage capacity will be entirely exhausted in another 35 years.

Zuni Reservoir, on the Zuni River at Blackrock, N. Mex., lost 76.5 percent of its capacity between 1907 when the dam was completed and July 1932. The rapidity with which storage was being lost became so serious by 1923 that protective works to hold the silt on the watershed were begun that year on Rio de Los Nutrias, the principal silt-producing tributary. In July 1931 a hole was blasted in the gate tower for installation of a 4- by 6-foot sluice gate, which was completed on October 15, 1931. In the 3-month interval it was possible to sluice out of the reservoir only about 500 acre-feet of a total of 11,960 which had been deposited. Sluicing operations have continued each year whenever water was available, but without materially adding to the available storage space.

Survey Shows Loss

Elephant Butte Reservoir on the Rio Grande, 120 miles above El Paso, Tex., supports an agricultural development having an estimated value of more than $100,000,000. Without the stored water available for irrigation in this reservoir probably nine-tenths of this wealth would disappear. A survey of the reservoir in 1935 shows that 13.8 percent of its capacity has already been lost by silting which represents an average rate of depletion of 0.68 percent a year. If this rate should continue, an additional 84 years would see the capacity equal only to the normal annual draft, at which point any further depletion not compensated by new storage facilities would mean progressive decline in the valuation of most of the dependent developments to the point of exhaustion within a relatively few years.

Piedmont Reservoirs

In the southern Piedmont region practically all small reservoirs and many others of major size that are more than a few decades old are completely filled, except for a normal alluvial stream channel through the region of the original pond. There are literally scores of these smaller reservoirs, with dams 10 to 30 feet high, equipped to generate power running generally from 20 upwards to 500 horsepower, and for larger nondistributing plants up to 4,000 horsepower. At place after place in this region, abandoned power plants and dismantled machinery now stand as gaunt reminders of the ravages of excessive sedimentation on storage capacities and plant equipment and operation. Altogether, these smaller plants generate an important aggregate power. Their intimate distribution and service among rural and small urban communities of the Southern States for grist mills, yarn and weaving mills, makes their gradual deterioration particularly grievous to large segments of the population.

Only Part of Picture

These few examples of the destruction being wrought yearly by excessive sedimentation resulting from accelerated erosion induced by deforestation, overgrazing, unwise land use, and unscientific agricultural practices do not adequately illustrate the total loss of water-storage resources in the Nation; neither do they present a fair picture of conditions the country over, for as yet properly evaluated data on many regions, particularly the more northern States, are lacking. The data at hand, however, clearly show that not only is reservoir silting a problem of first magnitude in many regions, but also that the silting rates are neither uniform nor fixed in the different sections of the country but vary from place to place and from time to time, with respect to erosional production of debris in the watershed areas and with adjustment of reservoir capacity and shape to the size and characteristics of the watershed.

Roosevelt Reservoir, Salt River, Ariz. Mud cracks on drying silt surface exposed by lake drawdown. Background shows the width and depth of mud fill.

Notwithstanding the fact that preliminary estimates based on incomplete data furnished by State officials throughout the country indicate the existence of more than 1,200 storage reservoirs and more than 10,000 dams involving invested capital of several billion dollars, virtually no efforts have been made specifically to protect and preserve these indispensable resources from the common menace of exhaustion by silting.

This seeming apathy may be attributed, first, to almost universal failure to recognize or appreciate the excessive rates at which water storage is being lost in areas of accelerated erosion, and second, to a lack of fundamental knowledge on which effective remedial measures might be based. It has been, all too commonly, the accepted thought among engineers that reservoir storage would last until the project paid out, disregarding the danger to the social security of populations dependent upon such works. The seriousness of the situation is shown by the inroads already made upon developed reservoir resources, many of which are now exhausted, many more of which are in immediate danger within the coming generation, and few of which promise to outlive our known reserves of coal and iron unless early steps are taken to reduce and control excessive silt production at its source.

Previous Work

Previous to inauguration of sedimentation studies by the Soil Conservation Service, the records showed only 31 reservoir-sedimentation surveys in the entire country. By States, they included seven in Texas, four in California, three each in New Mexico and Tennessee, two each in Iowa, Wyoming, Colorado, and Ohio, and one each in Arizona, Oregon, Illinois, Minnesota, Maryland, and North Carolina. These surveys diverged widely in field methods and manner of computation. Several could be classified as little more than estimates, while on others the data were insufficient.

The total literature on silting of reservoirs in this country is confined to two Government bulletins, one State and one Federal, both relating primarily to the State of Texas, and less than one dozen original references in various engineering journals.

Work to Date

Studies of the silting of reservoirs were begun as a part of the soil conservation research program in July 1934.

The subsequent work has been greatly facilitated by the generous cooperative assistance of various Federal, State, and municipal agencies and many individuals in position to give indispensable information and aid. Important items of the program have been carried out under formal and informal cooperative arrangements with the United States Bureau of Reclamation, United States Coast and Geodetic Survey, United States Geological Survey, United States Forest Service, United States Bureau of Indian Affairs, Bureau of Agricultural Engineering, and the State water boards of Texas and Illinois. Acknowledgment is also due to the numerous municipal water

boards, industrial concerns, and field operations offices of the Soil Conservation Service for assistance rendered.

In January 1935 three field parties of six technical men each were assembled and assigned to the southeastern, the south central, and the southwestern regions of the country. Through February 1936 reservoir investigations have included detailed surveys of 30 representative reservoirs and reconnaissance examination of more than 250 others.

Range of Survey

The reservoirs chosen for survey have varied in size from small headwater ponds of 18 acres surface,

Five-foot targets marking range end for sounding. White Rock Reservoir, Dallas, Tex.

draining a watershed equivalent to only two or three moderate-sized farms, to the immense Elephant Butte Reservoir on the Rio Grande in New Mexico, covering more than 40,000 acres and draining an area larger than the State of West Virginia, and Lake Mead above Boulder Dam on the Colorado River in the Southwest, which will impound the largest artificial body of fresh water yet contrived. The watersheds have been almost as diverse in land utilization as the reservoirs are in size. They have been representative of the rolling corn and tobacco lands of the southern Piedmont, the rich cotton-producing "black lands" and the higher grazing plains of Texas, the rugged Ozark foothills of the Arkansas-Missouri boundary, the arid plateaus and basins of Arizona and New Mexico, and the national forest and agricultural watersheds of California.

In addition to individual reservoir surveys, a State-wide reconnaissance of reservoir silting has been completed in Alabama, North Dakota, and South Dakota, and is now under way in North Carolina, Illinois, and California.

The present organization of personnel on this project includes three geologists detailed to reconnaissance investigations and three field parties consisting in each case of an engineer, a geologist, and four engineering aids of varied engineering and geological training.

Reasons for Study

Why should a survey be made of the amount of mud in a lake, when we all recognize it must be filling, from observation of erosion on the hills? Would it not be wiser to allot the same amount of money for dredging a lake or erecting a barrier at its head to catch the silt? Aside from the obvious disparity between relative costs of such operations and of research studies, the same questions might be suggested with equal logic to a flood. After all, we see the rainfall and we can tell by the height of the water in the river and number of people on the banks that a flood is in progress.

Why, then, study the effects of the flood and count the economic loss? It is, of course, so that we may be able, if humanly possible, to prevent a recurrence of the same destruction, so that we may determine the kind and height of flood protection works that are needed; and for more advanced students, so that we may understand and propagate sounder measures to check floods at their source. In the same manner, reservoir surveys and related special studies are undertaken to determine present silting rates and predict future trends, so that we may be prepared to take steps necessary to lessen silting rates by recommending watersheds most needful of soil-conservation planning, and by developing methods for abating the silting rate supplementary to established erosion-control practices.

The reasons for study of reservoir sedimentation are several. They fall naturally into three groups—first, those of assistance in planning the erosion control program of the Service, with respect to agricultural development; second, those related to protection of the reservoirs themselves which, together with flood control, comes under the broader scope of protecting all the Nation's resources from the menace of accelerated erosion; and third, those concerned with advancement of scientific knowledge of the processes and principles of transportation and emplacement of erosional debris. These reasons are taken into account in the scope and objectives planned for the project of reservoir investigations.

A complete inventory is being made, State by State, of the reservoir resources of the Nation and the effects of silting on their rate of exhaustion.

This will comprise full collection of data on reservoir characteristics, including storage capacity, surface area, use, type and size of dam, and area of drainage basin. The reservoirs of each State and physiographic region will be classified according to type, size, use, and tributary watershed characteristics. In addition, data will be collected and estimates made on the economic values involved in reservoir storage, and the effects of depletion by silting on the total water-storage resources of the country. Lastly, this Nation-wide inventory will serve as a basis for selection of the most significant examples in each State for detailed surveys and special studies.

Future Reservoir Planning

Detailed sedimentation surveys of individual reservoirs being made in regions of various types will afford a sound basis for future reservoir planning and design. Heretofore, most reservoirs have been constructed without adequate data on which the life span of the storage basin could be reliably predicted. In numerous instances, this has resulted in total exhaustion or critical impairment of storage even before the initial cost of the reservoir has been amortized. A series of widely scattered and representative surveys correlated with determined watershed conditions is expected to influence the locations, the sizes, and the dam designs of future reservoirs, by making available definite information on the prospective rates of silting. With such data, it will be possible to prevent considerable economic loss by adjusting reservoir plans to watershed characteristics.

Erosion Measurement

The detailed surveys of reservoir silting will establish controls for measurement of average net erosion in representative drainage basins. A quantitative survey of sediment in any reservoir is a measurement of erosional debris delivered from its tributary watershed during the life span of the storage basin to the date of survey, minus the fraction that has escaped past the dam in outflowing water. It is not in itself a measurement of total erosion in the watershed, but through correlation with detailed watershed surveys of soil, slope, climatic and vegetative conditions, including local plot measurements and special studies, it is expected that an evaluation factor will be derived to express the net average rate of erosion for the watershed as a whole. For that reason, it is particularly important that reservoir studies should be not only widely scattered geographically, but should include a range of reservoir types, draining watersheds varying from a few fields to thousands of square miles and taking in the greatest possible variation of watershed conditions. Reservoir studies are of particular value in indicating and affecting choice of those areas demanding priority of effort in propagating effective erosioncontrol practices. Since all initial reservoir surveys are accurately monumented, it will be possible to repeat the measurements from time to time to establish progressive trends in silting rates as reflecting constantly changing watershed conditions, and particularly the changes due to accelerated erosion and erosion control.

Close-up view of 6-foot silt sampling spud and sounding pea.

Supplementary Control Methods

Special studies of the processes and characteristics of reservoir sedimentation are being made in order to develop methods of silt control supplementary to established erosion control practices. It is recognized that widespread and completely effective erosion control, even throughout the agricultural regions of the country, will not be established in the course of a few years. On the semimarginal, arid, and desert lands, particularly of the Southwest, erosion will not be reduced to its geologic norm on a widespread scale for many generations, if ever. Thus we may anticipate silt production, transportation, and deposition in our reservoirs as a continuing process for an indefinite period of time, though of diminishing order in many regions as erosion control becomes more effective. Temporary abatement of reservoir-silting rates by developing methods of partially bypassing silt through reservoirs, by permanently controlling particular sources of silt production and by studied em-

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PARTY "SHOOTS" COLORADO RIVER GORGE FOR SILTING AND EROSION INFORMATION

By Solon R. Barber

Danger below! Two of the boats making ready to head off down the rowdy Colorado. All instruments and supplies were carried in water-proof boxes.

Silt-clogging of the Boulder Reservoir and of the quiet pools higher up the Colorado River is caused by soil erosion on the river's watersheds and, it is hoped, can largely be controlled at the source by proper soil-control measures.

Preliminary reports of a recently completed Soil Conservation Service surveying expedition down 55 hazardous miles through the Lower Granite Gorge of the Colorado, never before precisely surveyed, show that the bulk of the silt washed into the reservoir comes from a relatively small area of watershed.

This silt, once valuable soil, is blown and washed down into the river from the high plateau watersheds in the Navajo Indian Reservation in northeastern Arizona and the Ute Indian country in northwestern New Mexico, and is beginning to fill one of

Huge silt beds along a relatively quiet pocket of the Colorado River, ready to break off and be carried down the swift river.

The expedition carried an efficient portable radio set and river station KBAZ functioned at camping grounds along the route.

Uncle Sam's newest and most valuable water-storage reservoirs.

The surveying expedition, headed by Edward A. Schuch of the Service, involved aerial, ground, and hydrographic measurements and mapping of the Colorado River from the mouth of Diamond Creek to a location 6 miles below the present high-water mark of the reservoir, and furnished the most accurate information on the region thus far secured. So precise were the surveys that the error was less than 1 foot in 20,000 feet.

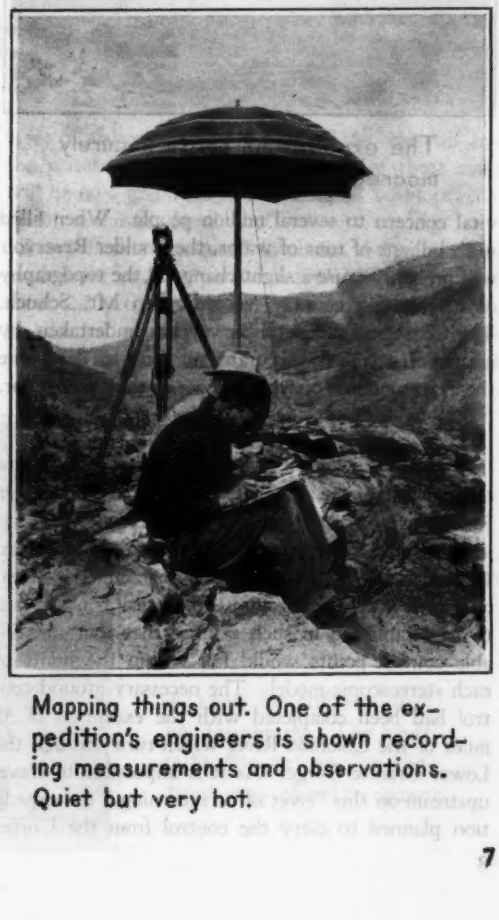
"The expedition found deposits of silt as much as 10 feet deep and 300 feet wide in pockets and pools above Pierce's Ferry", Mr. Schuch reported.

"In order to negotiate the dangerous rapids of the river, the party used four special nonsinkable boats built of Philippine mahogany. Supplies and equipment were carried in waterproof boxes, since every precaution had to be taken to protect the delicate and valuable instruments. Twelve men composed the party: engineers, survey specialists, experienced rivermen, and a guide.

"Information obtained by the expedition will be valuable to the Soil Conservation Service in working out plans to protect the large population who depend upon the water supply gained by damming the Colorado and to additional thousands who live on the Navajo and Ute plateaus where accelerated soil erosion is an all-too-painful reality."

Erosion Control Dire Need

The gates of Boulder Dam were officially closed on February 1, 1935. Late last autumn, the water in the reservoir rose nearly 300 feet higher than the original river level. When the lake is filled, it will be approximately 130 miles long and 600 feet deep. Its water will supply countless city homes, power plants, farms and orchards. Control of erosion with its resultant silting and sedimentation thus becomes of



Mapping things out. One of the expedition's engineers is shown recording measurements and observations. Quiet but very hot.

The expedition's boats securely moored in a quiet pool.

vital concern to several million people. When filled with billions of tons of water, the Boulder Reservoir will probably cause a slight change in the topography of neighboring country, according to Mr. Schuch. The Coast and Geodetic Survey has undertaken, by means of extremely accurate surveys, to determine the exact amounts of such changes as they may occur.

Careful Survey Required

About a year ago, it was decided that an accurate contour map of the area that will comprise the Boulder Reservoir is necessary in order to carry out the Service's silt and erosion studies in the Colorado Basin. In order to map this area by photogrammetric methods, a network of horizontal and vertical controls had to be established in such manner that four identifiable control points would fall within the limits of each stereoscopic model. The necessary ground control had been completed with the exception of 55 miles of the Colorado River which runs through the Lower Granite Gorge. As it is impossible to travel upstream on this "river of no returning," the expedition planned to carry the control from the United States Coast and Geodetic Survey stations at Peach Springs down through Peach Springs Canyon into Diamond Creek and then down the Colorado to Pierce's Ferry. Mr. Schuch, as chief photogrammetrist of the Service, was placed in charge of the expedition. He was assisted by George McGathen, a civil engineer in Government service.

The survey party left Diamond Creek September 26, 1935, and headed downstream. The survey was completed in 45 days.

Radio Station Set Up

The expedition fully understood the necessity of keeping in close and rapid communication with Washington, D. C., headquarters and stocked an efficient portable radio set. River station KBAZ was set up in the camps and messages were relayed through the courtesy of the United States Forest Service Desert Range Station, KBAY, Milford, Utah, to Los

Watch those boulders! One of the expedition's nonsinkable boats "shooting" the rapids of the Colorado. The boats sped down, stern first, the boatman rowing against the current.

From the heights. Three 17 foot boats of the expedition speeding down the Colorado River, pale into insignificance against the looming stone walls of Lower Granite Gorge.

Angeles and Washington. Messages and findings were radioed daily, with the exception of 1 or 2 days when wind and rain storms whipped through the winding passes.

Radiogram, November 11, 1935, Station KBAZ to KBAY:

> We are camped just above Separation Rapids. Will be here 2 or 3 days. In 1869 a party separated at Separation Rapids. A bronze tablet on the side of the canyon wall tells about it.

The party that separated was the famous Powell Expedition.

Radiogram, November 10, 1935, Station KBAZ to KBAY:

> We are using about 40 pounds of food per day. Will have enough food with that which is cached to last 35 to 40 days from now. The survey work is going faster. We were able to make seven stations.

These terse messages, reporting findings, requesting information, giving camp and field locations, came out nightly from the pitch-dark depths of the Colorado gorges. That portable radio was the men's one means of keeping in touch with the world above them. Mr. Schuch reported that, outside of the members of the expedition, not a soul was seen while they were working along the floor of the mile-high canyon.

Now that the first survey of the region has been completed, specialists have set to work to bring together all the findings secured by the expedition in a set of elaborate contour maps of the reservoir and the watershed areas involved. Some of these maps will be on a grand scale, one being on a 10-foot scale drawn in minute detail.

Every facility was used to obtain the information needed for making precise maps. The party took about 2,500 feet of motion pictures, some in colors. In addition, several hundred still photographs were taken. The pictures will be extremely useful not

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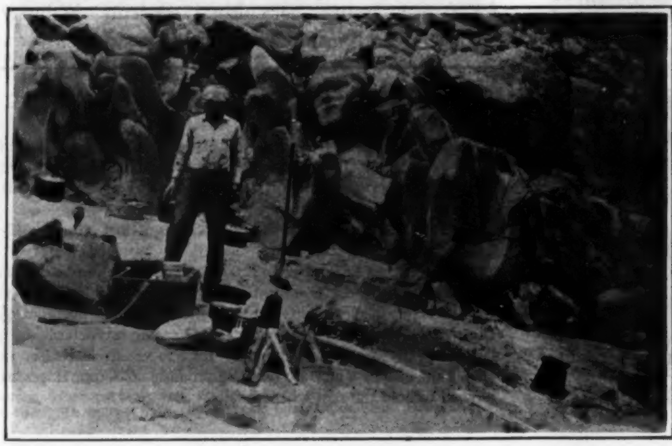


A stop for coffee--but no doughnuts. The chef puts the pot on for the tired men about to appear.

HYDRAULIC STUDIES OF EROSION CONTROL

By J. T. McAlister [1]

Work began on a field hydraulic laboratory at Gilreath's Shoals on Beaverdam Creek near Tigerville, S. C., in August 1935, under the direction of Prof. R. C. Johnson, of the University of South Carolina, consultant engineer for the Soil Conservation Service, and D. W. Cardwell, junior agricultural engineer. Labor was furnished by C. C. C. enrollees from Camp Buie. A reservoir at the laboratory impounds approximately 500,000 gallons of water. The dam is a gravity-section rubble masonry type having a spillway crest 5½ feet deep, which takes care of flood flows. It is set in a natural key in the bedrock at the head of shoals which drops 40 feet in 200 feet. This unusual fall allows for ample test-channel space around the side of the hill where the experimental set-up joins the main supply channel from the reservoir.

Arrangement of Control Channel

The control channel in which the water is measured in cubic feet per second is arranged so that water enters through a large control gate which can be adjusted for required amounts of flow. A loose rock baffle stills the water before it passes on to a 24-inch Gurley hook gage placed back of a sharp-crested pine weir, 3 feet wide and topped by a 1-inch strip of copper. The weir is calibrated and shows the normal creek flow to be from 1 to 2 cubic feet per second, varying, of course, with the season. With the headgate open, the maximum flow of water is about 12 cubic feet per second, obtained for a short period of time.

Dam To Be Raised

Plans have been made to raise the height of the dam by 2 feet in order to increase the quantity of flow in the test channel.

The headgate control channel is to be extended in order to improve the entrance conditions and the method of measuring the amount of flow.

In general, the experimental work has been limited to conditions peculiar to the Piedmont area. However, some of the data are applicable to other sections.

The test channel is such that full-size structures may be installed and a complete study of the function of structures may be made before field construction begins. The proper method of construction may be determined and the proper recommendations made. In this way proposed field installations are studied in a systematic manner and many failures in the field are eliminated.

Tests Being Made

Tests which have been completed or are in progress include:

1. Determination of the proper discharge coefficient of rectangular masonry notches for vertical overfalls.
2. Development of information concerning stabilizing soils with portland cement for use in erosion-control structures.
3. Determination of proper designs of dams, baffles, flumes, and high-velocity channels and studies of the permissible velocities for different types of vegetative treatments.

One experiment of particular interest utilizes two terraces which will be tried under conditions similar to a heavy rain. Data as to the proper terrace specifications will be obtained. By planting the terrace intervals, the erosion-resisting qualities of various crops are to be ascertained.

The field laboratory provides an opportunity for technical and construction supervisors to observe the action of water on actual field installations.

Demonstrations have also been held at the laboratory for farmer groups, agricultural students, highway engineers, and maintenance superintendents.

[1] The author is agricultural engineer, Soil Conservation Service, Spartanburg, S.C.

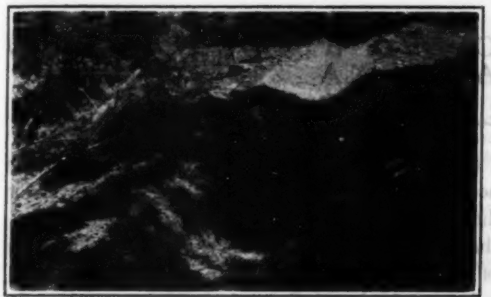
WIND EROSION IN UTAH

Holes as large as 6 acres in area and as deep as 15 feet are reported as having been blown in once-valuable grazing lands of Utah, where the Soil Conservation Service maintains its Tooele-Grantsville demonstration project.

One recent 8-hour windstorm left 76 pounds of dust on a 9-by-12-foot rug in a tightly built house.

A transcontinental airplane at 22,000 feet encountered dust in such quantities that it was forced to turn back, in the interest of safety.

Dust storms in this locality are attributed largely to overgrazing, and the Soil Conservation Service is undertaking revegetation on a large scale. Crested wheat grass, introduced from Russia, is among the grasses which are showing promise. Contour ridges are plowed to hold the rain where it falls.

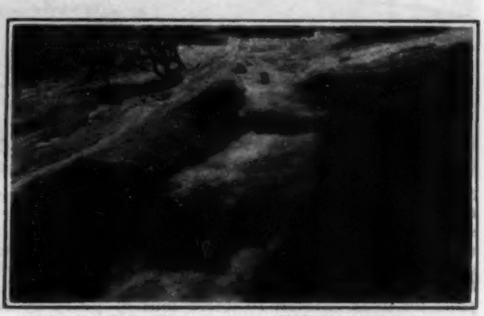


BERMUDA SOD FLUME ON A 22½ PERCENT SLOPE BEFORE WATER WAS ALLOWED TO ENTER.

BERMUDA SOD FLUME SHOWING FLOW OF WATER WITH A VELOCITY OF 14 FEET PER SECOND.

BERMUDA SOD FLUME AFTER WITHSTANDING A VELOCITY OF FLOW OF 14 FT. PER SECOND FOR 25 MINUTES. BERMUDA SOD WAS PLACED 2 WEEKS BEFORE EXPERIMENT.

A GENERAL VIEW OF THE HYDRAULIC LABORATORY LOCATED ON BEAVERDAM CREEK NEAR TIGERVILLE, SOUTH CAROLINA. THE CONTROL GATE AT THE ENTRANCE OF THE MAIN TEST CHANNEL IS SEEN IN THE FOREGROUND.



A FLOW OF APPROXIMATELY 10 CUBIC FEET PER SECOND.
1-A TWO INCH THICK CONCRETE BAFFLE. 2-A FOUR INCH THICK RUBBLE CONCRETE BAFFLE. 3-A SIX INCH THICK STABALIZED CLAY BAFFLE.

BAFFLE STRUCTURES SHOWING SEVERAL HOURS OF FLOW AT THE RATE OF 10 CU. FT. PER SECOND. NOTE THE SCOURING DOWNSTREAM FROM BAFFLES.

BAFFLE STRUCTURES AFTER APPROXIMATELY DOUBLE THE TIME OF FLOW.

HOW GULLIES ARE CONTROLLED BY VEGETATION IN SOUTH CAROLINA

By George L. Harmon

Gully on farm in South Carolina, caused by improper terracing of fields.

Same gully after banks were sloped by bulldozer, terrace lines surveyed and contour terraces constructed. Diversion ditch at head diverts flow of water from surrounding drainage area. Bermuda grass shown fringing the drainage area, being established by sodding on terrace ridges. Water that falls on area carried to lower end of gully by terrace channels. Entire area seeded to mixture of small grain. Black locust trees planted during past season.

In South Carolina vegetation is proving adequate for the control of a number of large gullies. Not only is it giving permanent protection against erosion, but it is also affording food for wildlife, grazing for livestock, and trees for fuel, fence posts and building materials.

We divert the flow of water when that is possible. We usually cut a diversion ditch above the head of the gully or accomplish our purpose by so terracing the land as to drain away the water. We like to lead the diversion ditch into a woodland or some other protected area. In some instances, particularly when a gully occurs in a large cultivated field, we find it necessary to protect the water channel or diversion ditch. Narrow bands of Bermuda grass sod are used, the distance between them varying with the steepness of slope. If it is not possible to use a diversion ditch, a flume sodded with Bermuda is used to conduct the water into the channel of the gully. When the heads of gullies are perpendicular, as is usually the case, it is necessary to cause the water to "walk" rather than run down the sloped portion, thus reducing the cutting power to a minimum.

Sloping Gully Banks

Gully banks are sloped as an aid to controlling gullies by vegetative methods. Sloping is done by the use of a bulldozer or explosives, or by hand labor. The first method, being the most economical, is preferable. The gully banks are usually brought to a grade not greater than 40 percent. Soil pushed in raises the bottom of the gully by several feet.

Contour Terracing

Contour terracing has proved very satisfactory on the sloped banks. In constructing these contours, terrace lines are surveyed so as to drain the water from the area being treated to protected areas on either side. A ridge is then built on the surveyed line resembling the farmer-built, "bench-like" terraces. The ridge is approximately 2 feet high and about the same width at the base. It is sodded on top with Bermuda grass or seeded to a mixture of small grain. The ditch on the upper side collects the water and carries it to the discharge point, either wooded or other protected area or into a protected water channel. Bands of Bermuda sod are placed in the gully channel perpendicular to the slopes. When the slope is very steep the channel is sodded solid with Bermuda.

If terraces are not constructed on the contour, the banks are planted to narrow strips of Bermuda sod, honeysuckle, or kudzu on the contour. The strips of Bermuda are approximately 2 feet wide, the vertical interval varying with the slope of the land. The entire area is then seeded to a close-growing annual plant. Small grains—rye, oats, and Italian rye—are

FROM TOP TO BOTTOM

Narrow strips of Bermuda grass placed on contour slopes and across channel of gully in Spartanburg County, S. C., in fall of 1934. Banks had been sloped with bulldozer. Diversion ditch at head diverts flow of water from adjacent territory into wooded area at left.

One year's growth of small grain and black locust trees in gully shown above. Picture taken in September 1935. Gully was formerly very active with perpendicular banks and approximately 35 feet deep before treatment.

Gully approximately 30 feet deep and rapidly advancing into woods, uprooting large trees.

The same gully after banks were sloped, contour terraces constructed and preparation made for planting vegetation. Gully is line between two farms and is the result of road water being discharged into the area. Diversion ditch diverts road water into nearby protected area.

used in the fall and winter, and lespedeza, sorghum cane, and Sudan grass are seeded in the spring and summer. These annuals serve as nurse crops until the grass or trees are well established. Black locust is planted at 4-foot intervals over the entire area and will provide permanent protection within a few years.

Some gullies are being treated with vegetation without sloping the banks. This method is the least expensive but does not bring about maximum control in as short a time as when the banks are sloped. A few gullies have been treated by direct seeding of black locust in narrow contour rows, while others have been planted to locust seedlings, honeysuckle, and kudzu crowns. We do not find it advisable to plant black locust and kudzu together.

Bermuda grass and black locust are at present the best plants in South Carolina for gully control. Bermuda is the only grass that will survive on badly eroded land. The locust makes a very rapid growth and will furnish fence posts for the farmer in from 8 to 12 years.

The South African Farmer reports that in the year ended August 1935, 5,500 applications for assistance has been received by the South African Department of Agriculture, which is making an effort to control soil erosion.

Experiments conducted at the Spur, Texas Station, show that buffalo grass retains 82 percent of rainfall, in comparison with 55 percent of by cotton.

PARTY "SHOOTS" COLORADO

(Continued from p. 9)

only in making maps but in the surveys to be undertaken later.

Objects of the Survey

The principal objective of the expedition was to gain information that will be used in the future in determining the rates of silting in the reservoir. Knowledge of these rates will be necessary for formulation of policies and practices of silt control on the watershed.

Soil wastage is denuding once valuable farm lands in the Navajo and Ute Indian country and impoverishing the Indians as well as the white settlers. Thickly-populated country in the Los Angeles metropolitan and southern California areas are particularly affected, since excessive sedimentation of the reservoir would threaten city water supplies, storage reservoirs, waterways, irrigation canals, and power plants.

"The Soil Conservation Service, in cooperation with other agencies, will make use of every known applicable method of erosion control in the areas affected", said H. H. Bennett, Chief of the Service. "These will include the limiting or halting of grazing on eroded and erodible areas; the planting of grass and other cover crops to bind the precious topsoil; the construction of check dams, wiers, and settling basins, and the use of any other necessary mechanical or vegetative erosion-control methods."

Extracts From Log

Logs kept by members of the expedition furnish interesting day-by-day records of the trip.

Food supplies consisted mainly of dried fruits, flour, beans, rice, coffee, canned meats, and bacon. On one or two occasions, fresh meat was killed along the river. Mr. Schuch reported that the men feasted on fresh meat on Thanksgiving Day—a young wild burro which was shot and from which the choice cuts were taken.

Camp sites were hard to find along the winding floor of the canyon. Some of the camps were pitched on small sand bars which would ordinarily be perilous. River reports received by the party warned the men of coming high water and consequent danger to their camp sites.

Water from most of the side streams feeding the Colorado was found to be bad. The party allowed the water from the main river to settle for drinking purposes. It was muddy, but usually better than water from the branches.

Separation Rapids and Spencer Rapids proved to be the most hazardous, but both were "shot" without injury.

"My first impression of the gorge", Schuch wrote, "reminded me of Paul Bunyan's stories of the Powder River in Montana, which he described as a mile wide and an inch deep. The gorge could be described as the Powder River turned on edge."

STUDIES OF SILTING

(Continued from page 5)

placement of the silt load before it enters the reservoir is an objective of major importance. The special research investigations being inaugurated include studies of delta and up-valley sedimentation and means of permanently fixing this sediment through inexpensive engineering structures and vegetative control; studies of wave erosion on shore lines and methods of its prevention; studies of topographic and geologic conditions favorable to temporary desilting basins adjacent to reservoirs; studies of the "tunneling" or underflow of silt-laden water through a reservoir and possible means for utilizing this phenomenon in bypassing silt such as modified dam design; studies of the physical and chemical properties of reservoir silt and its value or harm if applied to agricultural lands; and studies of sources of silt with a view to controlling particular source areas which may be furnishing an abnormal ratio of the total incoming sediment.

Silt Measurements During Potomac River Flood

On Thursday, March 19, 1936, during the height of the Potomac River flood, Carl B. Brown, of the Division of Research, collected a sample of water which contained a very striking silt content. This sample was taken from an abutment of Chain Bridge, 5 miles above Washington on the Virginia side. Being from the upper foot of water moving downstream, and farthest removed from the center of the current, which was flowing at approximately 25 miles per hour, it should represent the minimum content of suspended load being carried by the river.

According to analysis by the United States Geological Survey, the sample had a content of suspended matter of 5,420 parts per million, or more than 0.5 percent suspended matter. At the time this sample was collected the estimated discharge of the river was between 390,000 and 400,000 second-feet. If this tremendous discharge contained as a minimum 0.5 percent solid matter, the Potomac River was moving down to the sea at this stage 2,000 cubic feet of silt per second or 7,200,000 cubic feet per hour.

FLOOD CONTROL WORK IN ITALY

By Albert Chiera[1]

Control of the watershed Sorgenti del Sele by reforestation.

In Italy, where artificial means of control have been extensively used, floods have continued to occur regardless of dams or the usual type of levees. Because of this, extensive reforestation is now being undertaken on denuded mountain sides.

The accompanying photograph evidences the potential power of vegetation to restrain run-off waters. With the multiplication of such works as these, Italy expects to accomplish the control of many mountain streams and the reduction of floods.

On the plains a supplementary method of control consists in moderating the effects of floods by allowing a river laden with sediment to spread out, lose its velocity, deposit silt, and build up lowlands. A series of levees is built, subdivided at intervals by cross levees, to form a network of huge catch basins. The first line of levees is broken up by openings to permit the water of the river, when rising, to flow into the catch basins and be impounded by the closing of sluice gates. The water, losing its velocity, deposits its silt, and when clarified is permitted to flow back to the river upon recession of the flood. By successive inundations the land is built up.

These catch basins during floods act as temporary reservoirs, to be silted up as a last objective, so that finally the land is raised above the possibility of flooding. This method of meeting the flood problem is described in A. Fanti's book *La technica e la pratica delle Bonificazioni*, but it is on the reforestation of denuded mountain slopes that Italian engineers are chiefly relying for a definite solution.

[1] The author is translator and research assistant in the Soil Conservation Service.

Will Direct Woodland Management

John F. Preston has been appointed head of the Section of Woodland Management, according to announcement by H. H. Bennett, Chief of the Soil Conservation Service.

Beginning in 1907, Mr. Preston served in the Forest Service for 18 years. This association included periods as supervisor of the Beartooth and Blackfeet Forests in Montana, chief of the branches of operation and forest management in Montana and northern Idaho, and work in forest management at Forest Service headquarters in Washington, D. C. For the last 10 years he has been forester for a large paper company.

BOOK REVIEWS AND ABSTRACTS

By Phoebe O'Neall Faris

A Contribution from The Soil Conservation Service Library

MICHIGAN WATERFOWL MANAGEMENT. By Miles David Pirnie. 1935.

The author's chief concern is to present the topics which are most pertinent to the efficient handling of present and future waterfowl problems. Of particular interest are the notes on nesting and migratory habits of dabbling ducks, diving ducks, mergansers, wild geese and swans, coots and grebes, and the double-crested cormorants.

The mallards—especially vigorous birds, which because of the migratory-bird treaty with Canada are still plentiful in the northland—haunt brushy marshlands where there is abundance of sedges and cat-tails. Their nests, little more than hollows on the ground, are often found as far as half a mile from the water. The eggs are greenish white, and clutches average 11 or 12. When incubation is advanced, a roll of soft down from the breast of the old duck encircles the nest and serves as a blanket to keep the eggs warm while the bird is away seeking food. In late April or May the broods hatch, and, soon after, the fluffy yellow and black ducklings, crowded in a tight cluster, leave the nest with the mother for their first swim. Within 10 weeks they are almost full-grown and able to fly, and by the last of July many broods are on the wing. It is in June that the drakes acquire their eclipse plumage, in which they no longer have green heads or gray bodies but resemble the dull coloration of the hens. The bills fade from rich yellow to olive green. Later, by another molt, the drakes again acquire their green head-dress and the bars of white which frame the iridescent green and purple patch of the inner wing feathers.

It is during these periods of incubation and molting that it is exceedingly important that mallards, and all other waterfowl, be protected from food shortage resulting from droughts or fires, from hunting mortality, and from disease.

Foxes, coyotes, hawks, serpents, pike, and snapping turtles, the great horned owl—these are the natural enemies of waterfowl; yet their depredations in duck colonies are small indeed compared with losses from such diseases as botulism and the protozoan disease, malaria-like in symptom and stages, which is transmitted by the bite of black flies. Little is known thus far about the diseases which destroy many wild swans, ducks, and geese, and it is suggested by the author that hunters, conservation officers, and other out-of-door people can render valuable aid by notifying the State Department of Agriculture or the Department of Conservation of any disease troubles in wild birds or in captive flocks, and by sending sick or dead birds to the State pathologists for examination.

As for waterfowl mortality from shooting, assume that a flock of 100 ducks or geese, healthy and strong, leave a northern breeding area in September. On their migration they are repeatedly fired upon and by the end of the shooting season just one-half or 50 of them may drop out, the victims of gunning, predators, diseases, and accidents. With even moderately good fortune, can the remaining 50 again restore the flock to the original 100 to start southward the following autumn? It is not likely. It is a problem for organized wildlife management and the waterfowl program.

The aims of waterfowl management in Michigan, where much wildlife research has been done, are summed up by Dr. Pirnie as follows: (1) To inventory waterfowl, both nesting and migrant; (2) to evaluate the destructiveness of gun, predators, diseases, and all other known destroyers of waterfowl; (3) to develop a plan for waterfowl protection, increase, and more widespread use and appreciation; (4) to improve conditions for waterfowl, especially in connection with water storage, fish, and fur production; and (5) to consider Michigan waterfowl questions and programs as a part of and not separate from the national waterfowl situation.

According to Dr. Pirnie's studies of the killing of leg-banded black ducks and mallards, the evidence piles up in favor of hunting restrictions, with the shorter season accompanied by low decoy and bag limits, and the importance of refuges and sanctuaries.

Dr. Pirnie has written extensively about the feeding habits and plant and animal resources of Michigan waterfowl. Widely varied is the diet of wild duck, goose, coot, swan, and grebe. From acorns to watercress, all down the line of succulent green pondweeds, and from crayfish to crane-fly larvae, the waterfowl eat their way through the seasons. It is in waters rich on organic matter, as where sod and logs are flooded at beaver ponds, that the coots, teal, and black ducks seem to thrive best, for there is to be found the great variety of plant and small animal food which they require.

Included in the book is a chapter on food and cover planting recommendations, with a table listing 28 plants, seasonal notations, and directions as to source and method of planting. This chapter is illustrated by a series of especially fine photographic plates.

There are notes on restocking and propagation of waterfowl species, predator control, and management programs.

The appendix contains a key to 50 aquatic plants of Michigan; notes on sample meals of ducks taken in Michigan; and a bibliography of references on waterfowl conservation and natural history. Pocket maps accompany the text. There are over 200 photographs.

THE LAND NOW AND TOMORROW. By R. G. Stapledon. London, 1935.

The author is professor of agricultural botany, University of Wales, Aberystwyth, and director of the Welsh plant-breeding station. His book deals, primarily, with planning for proper utilization of the land surface of Great Britain; or, to use his own expression, "the countryman's aspect of catering for posterity." The discussion involves many and various technicalities for land improvement and the conservation of fertility. Some of the subjects treated in detail are: Grassland reclamation versus reconditioning; cotton grass or Dyer's greenweed; Nardus or mat grass pastures; Molina or blue moor grass and fescue; permanent grass, Agrostis and ryegrass; reversion to bracken and rushes; excessive weediness; dairy pastures; the problem of grouse moors and sheep; the place of legumes and miscellaneous herbs.

Does it pay to sow wild white clover, to manure, to maintain land in high-class temporary grass? The author gives the results of his experiments in Wales in answer to these questions.

Afforestation and plantation arrangement in Great Britain is described, with numerous suggestions for recreational planning. An exceptional chapter on the national park is included, with accompanying topographical and vegetational maps. Aside from its technicalities, The Land Now and Tomorrow is a readable volume, propounding the many-sided ideals of the ruralist who loves the rural life. The chapters are illustrated by photographic scenes from the hills and valleys of the author's native Wales. The text is supplemented by an extensive bibliography on rural planning and agronomical subjects. There is an 11-page index.

A GENERAL INTRODUCTION TO FORESTRY IN THE UNITED STATES; with Special Reference to Recent Forest Conservation Policies. By Nelson Courtlandt Brown. 1935.

A general treatise on the subject of forestry, presenting types of forests; leading commercial tree species, with silvicultural systems of cutting and methods of artificial reproduction; nursery seeding and transplanting practices; the best logging methods; modern practices of lumber manufacturing and conditioning; wood uses and economics; reducing waste in forests and sawmills; forest products aside from lumber; methods of timber preservation, and directions for conducting forest research.

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